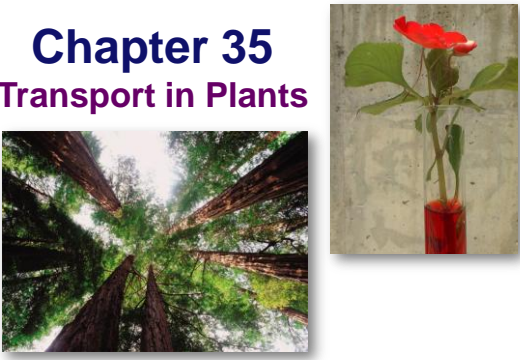


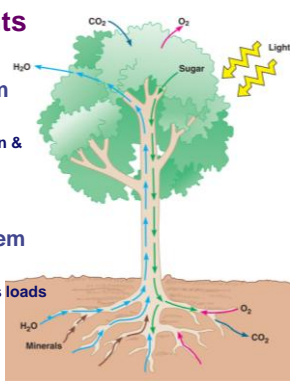
Chapter 35

Transport in Plants



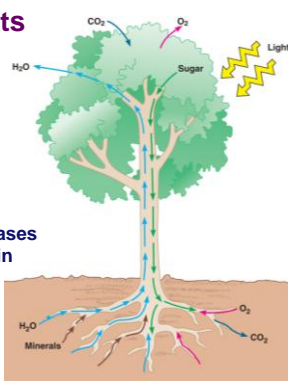
Transport in Plants

- **H₂O & minerals**
 - ◆ transport in xylem
 - ◆ transpiration
 - evaporation, adhesion & cohesion
 - negative pressure
- **Sugars**
 - ◆ transport in phloem
 - ◆ bulk flow
 - Calvin cycle in leaves loads sucrose into phloem
 - positive pressure



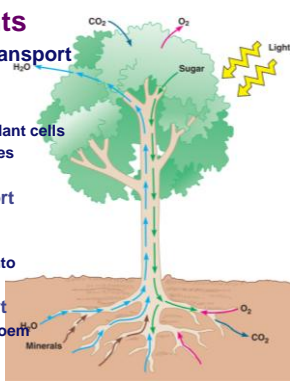
Transport in Plants

- **Gas exchange**
 - ◆ photosynthesis
 - CO₂ in; O₂ out
 - stomates
 - ◆ respiration
 - O₂ in; CO₂ out
 - roots exchange gases within air spaces in soil



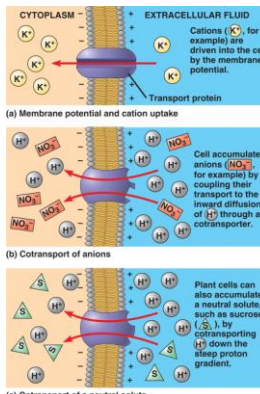
Transport in Plants

- **Physical forces drive transport at different scales**
 - ◆ cellular
 - from environment into plant cells
 - transport of H₂O & solutes into root hairs
 - ◆ short-distance transport
 - from cell to cell
 - loading of sugar from photosynthetic leaves into phloem sieve tubes
 - ◆ long-distance transport
 - transport in xylem & phloem throughout whole plant



Cellular Transport

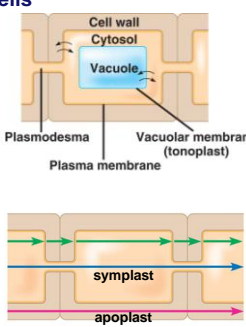
- **Active transport**
 - ◆ solutes are moved into plant cells via active transport
 - ◆ central role of proton pumps
 - chemiosmosis



proton pumps

Short Distance (cell-to-cell) Transport

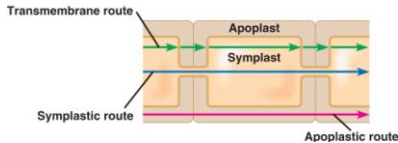
- **Compartmentalized plant cells**
 - ◆ cell wall
 - ◆ cell membrane
 - cytosol
 - vacuole
- **Movement from cell to cell**
 - ◆ move through cytosol
 - **plasmodesmata** junctions connect cytosol of neighboring cells
 - **symplast**
 - ◆ move through cell wall
 - continuum of cell wall connecting cell to cell
 - **apoplast**



Routes From Cell to Cell

Moving water & solutes between cells

- ◆ **transmembrane route**
 - repeated crossing of plasma membranes
 - slowest route but offers more control
- ◆ **symplast route**
 - move from cell to cell within cytosol
- ◆ **apoplast route**
 - move through connected cell wall without crossing cell membrane
 - fastest route but never enter cell



Long Distance Transport

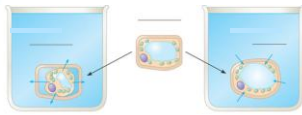
Bulk flow

- ◆ movement of fluid driven by pressure
 - flow in xylem tracheids & vessels
 - ◆ negative pressure
 - ◆ transpiration creates negative pressure **pulling** xylem sap upwards from roots
 - flow in phloem sieve tubes
 - ◆ positive pressure
 - ◆ loading of sugar from photosynthetic leaf cells generates high positive pressure **pushing** phloem sap through tube

Movement of Water in Plants



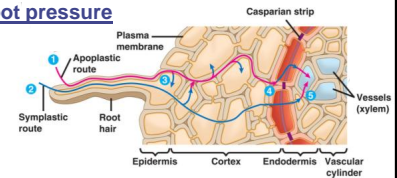
- Water relations in plant cells is based on water potential
 - ◆ osmosis through aquaporins
 - transport proteins
 - ◆ water flows from high potential to low potential



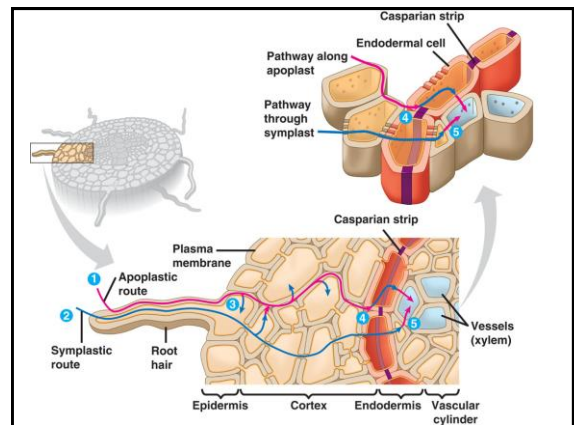
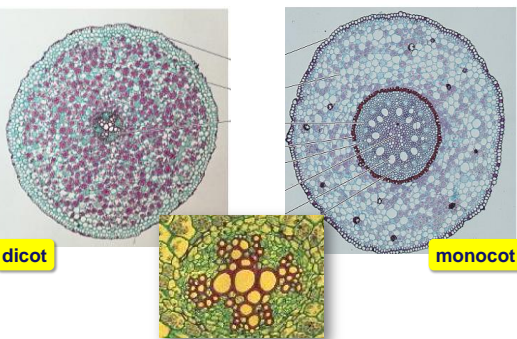
Water & Mineral Uptake by Roots

Mineral uptake by root hairs

- ◆ dilute solution in soil
- ◆ active transport pumps
 - this concentrates solutes (~100x) in root cells
- **Water uptake by root hairs**
 - ◆ flow from high H₂O potential to low H₂O potential
 - ◆ creates root pressure

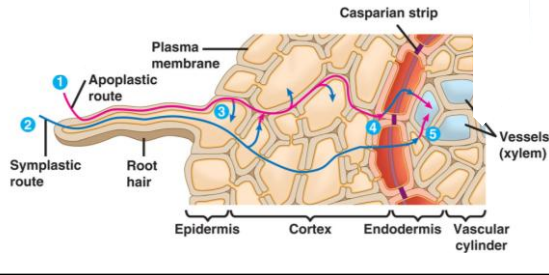


Root Anatomy



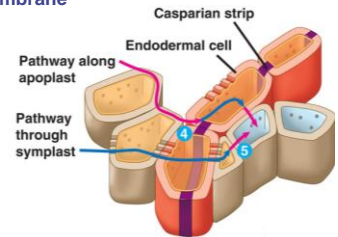
Route Water Takes Through Root

- Water uptake by root hairs
 - a lot of flow can be through cell wall route
 - apoplasty

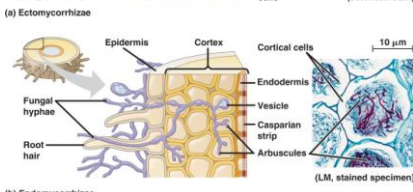
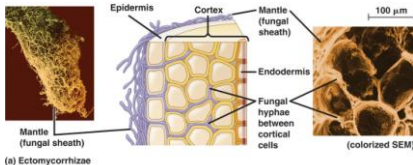


Controlling the Route of Water in Root

- Endodermis
 - cell layer surrounding vascular cylinder of root
 - lined with impervious **Casparian strip**
 - forces fluid through selective cell membrane & into symplast
 - filtered & forced into xylem vessels



Mycorrhizae



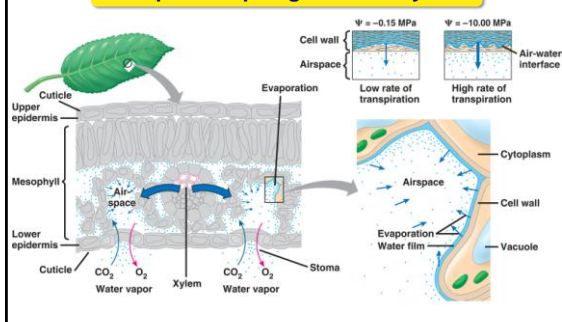
Mycorrhizae Increase Absorption

- Symbiotic relationship between fungi & plant
 - symbiotic fungi greatly increases surface area for absorption of water & minerals
 - increases volume of soil reached by plant
 - increases transport to host plant



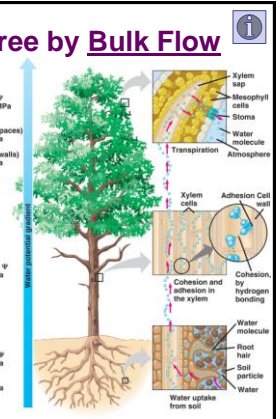
Ascent of Xylem "sap"

Transpiration pull generated by leaf



Rise of Water in a tree by Bulk Flow

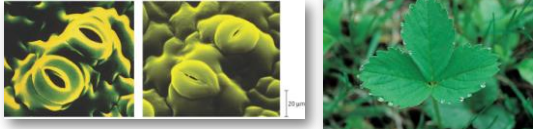
- Water potential
 - high in soil → low in leaves
- Root pressure push
 - due to flow of H₂O from soil to root cells
 - upward push of xylem sap
- Transpiration pull
 - adhesion & cohesion
 - H bonding
 - brings water & minerals to shoot



Control of Transpiration

Stomate function

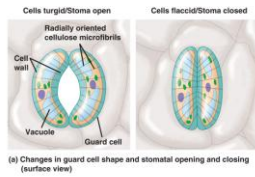
- always a compromise between photosynthesis & transpiration
 - leaf may transpire more than its weight in water in a day...this loss must be balanced with plant's need for CO₂ for photosynthesis
 - a corn plant transpires 125 L of water in a growing season



Regulation of Stomates

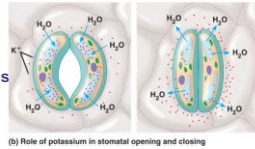
Microfibril mechanism

- guard cells attached at tips
- microfibrils in cell walls
 - elongate causing cells to arch open = open stomate
 - shorten = close when water is lost



Ion mechanism

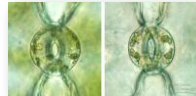
- uptake of K⁺ ions by guard cells
 - proton pumps
 - water enters by osmosis
 - guard cells become turgid
- loss of K⁺ ions by guard cells
 - water leaves by osmosis
 - guard cells become flaccid



Regulation of Stomates

Other cues

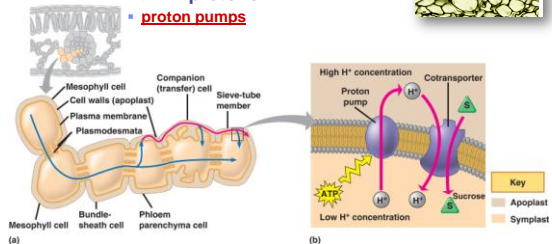
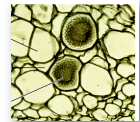
- light trigger
 - blue-light receptor in plasma membrane of guard cells triggers ATP-powered proton pumps causing K⁺ uptake
 - stomates open
- abscisic acid
 - plant hormone released by mesophyll cells that cause the stomata to close if the mesophyll water potential is too negative (too dry)
- depletion of CO₂
 - CO₂ is depleted during photosynthesis (Calvin cycle)
- circadian rhythm = internal "clock"
 - automatic 24-hour cycle



Transport of Sugars in Phloem

Loading of sucrose into phloem

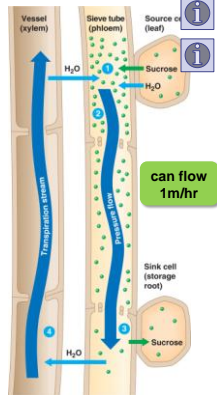
- flow through symplast via plasmodesmata
- active cotransport of sucrose with H⁺ protons
 - proton pumps



Pressure Flow in Sieve Tubes

Water potential gradient

- "source to sink" flow
 - direction of transport in phloem is variable
- sucrose flows into phloem sieve tube decreasing H₂O potential
- water flows in from xylem vessels
 - increase in pressure due to increase in H₂O causes flow



Experimentation

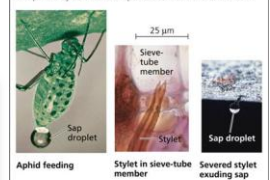
Testing pressure flow hypothesis

- using aphids to measure sap flow & sugar concentration along plant stem



Figure 36.19 **Inquiry** What causes phloem sap to flow from source to sink?

EXPERIMENT To test the pressure flow hypothesis, researchers used aphids that feed on phloem sap. An aphid probes with a hypodermic-like mouthpart called a stylet that penetrates a sieve-tube member. As sieve-tube pressure force-feeds aphids, they can be severed from their stylets, which serve as taps exuding sap for hours. Researchers measured the flow and sugar concentration of sap from stylets at different points between a source and sink.



RESULTS The closer the stylet was to a sugar source, the faster the sap flowed and the higher was its sugar concentration.

CONCLUSION The results of such experiments support the pressure flow hypothesis.